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Comparative Evaluation of Intraperitoneal Ropivacaine with Dexmedetomidine Versus Ropivacaine with Dexmedetomidine and Tramadol for Postoperative Analgesia Following Laparoscopic Cholecystectomy: A Randomized Double-Blind Clinical Study

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ABSTRACT

Background: Postoperative pain following laparoscopic cholecystectomy remains a significant clinical concern despite the minimally invasive nature of the procedure. Intraperitoneal instillation of local anesthetics combined with adjuvants has emerged as an effective multimodal analgesic technique for improving postoperative pain relief and reducing opioid requirements. This study was aimed to compare the analgesic efficacy of intraperitoneal ropivacaine with dexmedetomidine versus ropivacaine with dexmedetomidine and tramadol in patients undergoing laparoscopic cholecystectomy.

Materials and Methods: A total of 64 patients aged 18-65 years belonging to ASA physical status I and II undergoing elective laparoscopic cholecystectomy were randomly divided into two groups of 32 each. Group RD received intraperitoneal instillation of 0.25% ropivacaine with dexmedetomidine 1µg/kg, while Group RDT received 0.25% ropivacaine with dexmedetomidine 1µg/kg and tramadol 1 mg/kg. Postoperative pain was assessed using the Visual Analogue Scale (VAS). Duration of analgesia, time to first rescue analgesia, total analgesic consumption, hemodynamic parameters, and adverse effects were evaluated.

Results: VAS scores were significantly lower in Group RDT during the first six postoperative hours compared to Group RD ($p<0.05$). The mean duration of analgesia was significantly prolonged in Group RDT (5.84 ± 1.12 hours) compared with Group RD (3.76 ± 1.04 hours). Total postoperative analgesic consumption within 24 hours was significantly lower in Group RDT. Hemodynamic parameters remained stable in both groups without major adverse effects.

Conclusion: Addition of tramadol to intraperitoneal ropivacaine and dexmedetomidine significantly improves postoperative analgesia, prolongs analgesic duration, and decreases rescue analgesic requirement following laparoscopic cholecystectomy.

Keywords*: Laparoscopic cholecystectomy, Intraperitoneal analgesia, Ropivacaine, Dexmedetomidine, Tramadol, Visual Analogue Scale (VAS).*

INTRODUCTION

Laparoscopic cholecystectomy is currently considered the gold standard surgical procedure for the treatment of symptomatic gallstone disease because of its minimally invasive nature, shorter hospital stay, rapid recovery, and reduced postoperative morbidity compared with open cholecystectomy (1). Despite these advantages, postoperative pain following laparoscopic cholecystectomy remains a major clinical concern and may adversely affect early ambulation, pulmonary function, patient satisfaction, and overall recovery (2). The pain experienced after laparoscopic surgery is multifactorial and includes somatic pain originating from trocar insertion sites, visceral pain due to gallbladder bed

dissection and peritoneal stretching, and referred shoulder pain resulting from diaphragmatic irritation caused by carbon dioxide pneumoperitoneum (3).

Effective postoperative pain management is essential to facilitate early mobilization, reduce postoperative complications, shorten hospital stay, and improve surgical outcomes. Traditionally, opioids and nonsteroidal anti-inflammatory drugs (NSAIDs) have been used for postoperative analgesia. However, opioid administration is associated with several adverse effects including nausea, vomiting, respiratory depression, constipation, urinary retention, and sedation, which may delay recovery and discharge (4). Consequently, emphasis has shifted toward multimodal analgesic strategies that reduce opioid consumption while providing effective pain control.

Among the available multimodal approaches, intraperitoneal instillation of local anesthetics has gained considerable popularity because it directly targets visceral nociceptors present on the peritoneal surface and gallbladder bed (5). Ropivacaine, a long-acting amide local anesthetic with lower cardiotoxicity and neurotoxicity compared with bupivacaine, is widely used for intraperitoneal analgesia. It provides prolonged sensory blockade with minimal motor impairment and has demonstrated significant efficacy in reducing postoperative pain following laparoscopic procedures (6).

To enhance the quality and duration of analgesia, various adjuvants have been combined with local anesthetics. Dexmedetomidine, a highly selective α2-adrenergic agonist, possesses analgesic, sedative, and sympatholytic properties and has been shown to prolong analgesia when used with local anesthetics (7). Tramadol, a centrally acting analgesic with weak μ-opioid receptor agonist activity and inhibition of serotonin and norepinephrine reuptake, also exhibits effective postoperative analgesic properties and reduces opioid requirements (8). Previous studies have independently demonstrated the analgesic benefits of dexmedetomidine and tramadol as adjuvants in laparoscopic surgeries (9,10).
However, limited literature is available comparing the combined use of dexmedetomidine and tramadol with ropivacaine for intraperitoneal analgesia following laparoscopic cholecystectomy. Therefore, the present study was designed to compare the analgesic efficacy of intraperitoneal ropivacaine with dexmedetomidine versus ropivacaine with dexmedetomidine and tramadol in terms of postoperative pain relief, duration of analgesia, rescue analgesic requirement, and hemodynamic stability.

MATERIALS AND METHODS

This prospective randomized double-blind clinical study was conducted in the Department of Anaesthesiology at Prathima Relief Institute of Medical Sciences, Hanamkonda, Telangana after obtaining Institutional Ethics Committee approval and written informed consent from all participants from March 2024 to June 2025. A total of 64 patients aged between 18 and 65 years belonging to ASA physical status I and II scheduled for elective laparoscopic cholecystectomy under general anesthesia were enrolled
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Inclusion Criteria: Patient Aged between 18-65 years, ASA physical status I and II, undergoing elective laparoscopic cholecystectomy, body weight >50 kg and willingness to participate

Exclusion Criteria: Patient with allergy to study drugs, cardiovascular, hepatic, renal, respiratory, neurological disorders, pregnancy, lactation, chronic opioid use, alcohol abuse, conversion to open surgery and inability to understand VAS scoring.

Patients were randomized into two groups of 32 each using computer-generated randomization. Group RD received intraperitoneal instillation of 38 mL of 0.25% ropivacaine, Dexmedetomidine 1 μg/kg diluted in 1 mL and 1 mL normal saline, whereas Group RDT medicated with intraperitoneal instillation of 38 mL of 0.25% ropivacaine, Dexmedetomidine 1 μg/kg diluted in 1 mL and Tramadol 1 mg/kg diluted in 1mL. The study drug was instilled intraperitoneally in the gallbladder bed and beneath the diaphragm at the end of surgery before trocar removal.

Statistical Analysis

Data were extracted to Microsoft Excel sheet and analysed using SPSS version 26.0. Continuous variables were expressed as mean ± standard deviation. Independent Student's t-test and Chi-square test were applied. A p-value <0.05 was considered statistically significant.

RESULTS

Table 1: Demographic Characteristics of Study Participants (n=64).

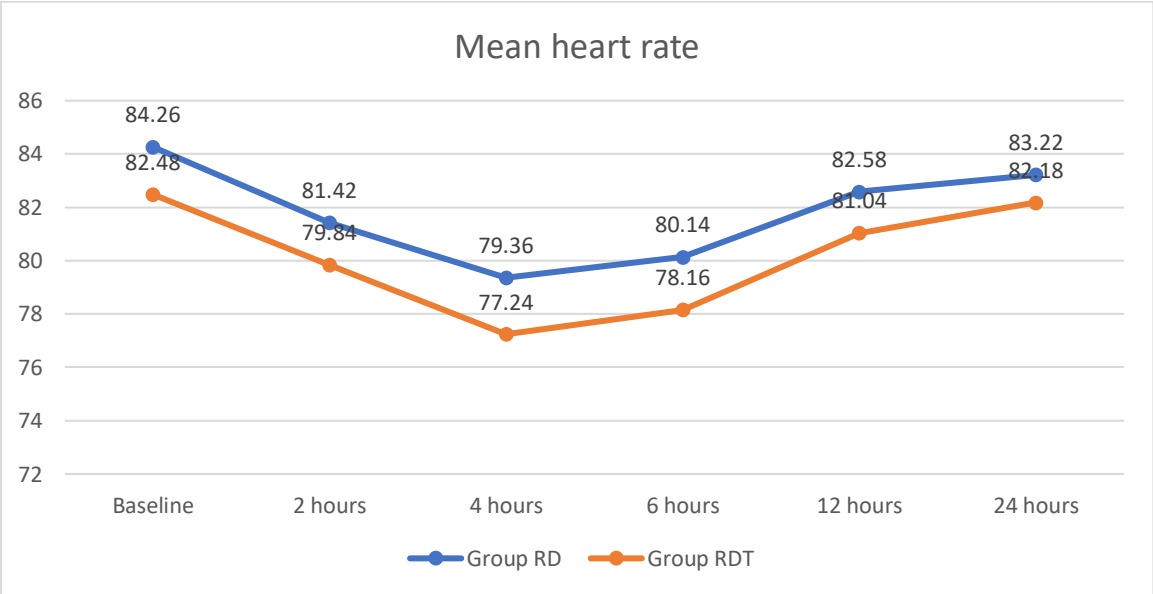
Demographic Profile	Group RD (n=32)	Group RDT (n=32)	p-value
Age (years)	44.62 ± 8.14	45.31 ± 7.96	0.732
Weight (kg)	56.28 ± 9.42	57.14 ± 8.86	0.684
Gender			
Male	14 (43.8%)	18 (56.2%)	0.312
Female	18 (56.2%)	14 (43.8%)	
ASA Grade			
Grade I	18 (56.2%)	19 (59.4%)	0.801
Grade II	14 (43.8%)	13 (40.6%)	

Table 2: Mean Postoperative VAS Scores at Different Time Intervals.

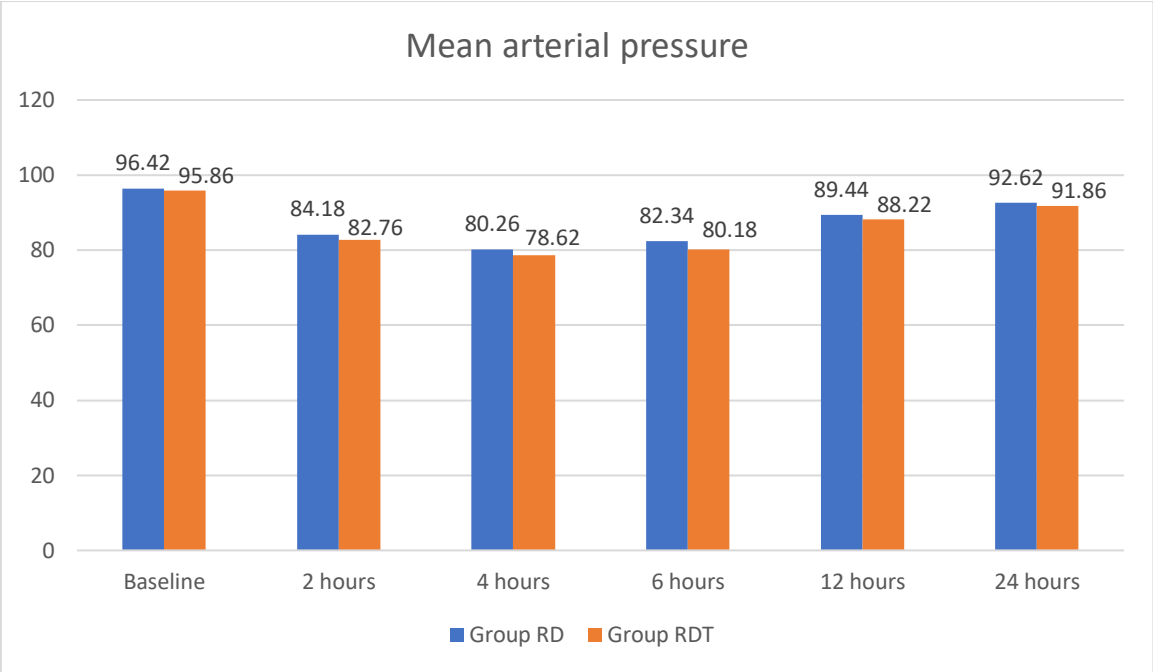
Time Interval	Group RD	Group RDT	p-value
1 hour	2.84 ± 0.72	2.18 ± 0.64	0.001
2 hours	4.12 ± 0.91	2.56 ± 0.68	<0.001
4 hours	5.28 ± 1.04	3.14 ± 0.82	<0.001
6 hours	4.96 ± 0.88	3.02 ± 0.76	<0.001
12 hours	3.62 ± 0.80	3.21 ± 0.71	0.061
18 hours	2.94 ± 0.62	2.72 ± 0.66	0.204
24 hours	2.18 ± 0.58	2.06 ± 0.54	0.412

Table 3: Details of rescue analgesia.

Parameter	Group RD	Group RDT	p-value
Time to first rescue analgesia (hours)	3.76 ± 1.04	5.84 ± 1.12	<0.001
Total analgesic consumption (mg)	182.65 ± 76.24	108.42 ± 39.16	<0.001
Number of Rescue Analgesic Doses			
One Dose	08 (25.0%)	20 (62.5%)	-
Two Doses	10 (31.2%)	10 (31.2%)	
Three Doses	09 (28.1%)	02 (6.3%)	
Four Doses	05 (15.7%)	00 (0%)	



Graph 1: Mean heart rate.



Graph 2: Mean arterial pressure.

DISCUSSION

Effective postoperative pain management following laparoscopic cholecystectomy remains an essential component of perioperative care because inadequate analgesia can delay ambulation, prolong hospitalization, and reduce patient satisfaction. Although laparoscopic procedures are minimally invasive, patients frequently experience significant visceral pain resulting from pneumoperitoneum, stretching of the peritoneum, and irritation of the diaphragm. Intraperitoneal instillation of local anesthetic agents has emerged as an important multimodal analgesic strategy aimed at reducing visceral nociception and minimizing opioid consumption.

The present study demonstrated that intraperitoneal instillation of ropivacaine with dexmedetomidine and tramadol (Group RDT) provided superior postoperative analgesia compared with ropivacaine and dexmedetomidine alone (Group RD). Patients receiving the triple-drug combination showed significantly lower postoperative VAS scores during the early postoperative period, prolonged duration of analgesia, delayed requirement for rescue analgesia, and reduced total analgesic consumption within 24 hours. These findings suggest a synergistic interaction between dexmedetomidine and tramadol when used as adjuvants to ropivacaine.

Ropivacaine is a long-acting amide local anesthetic widely preferred for intraperitoneal analgesia because of its lower cardiotoxicity and reduced motor blockade compared to bupivacaine. Its mechanism involves reversible blockade of voltage-gated sodium channels, thereby inhibiting nerve impulse transmission and visceral pain perception. Previous studies have demonstrated the effectiveness of intraperitoneal ropivacaine in reducing postoperative pain after laparoscopic surgeries. Kim et al. reported significant reduction in postoperative pain and analgesic requirement following intraperitoneal ropivacaine instillation after laparoscopic cholecystectomy. Similarly, Singh et al. observed improved postoperative comfort and prolonged analgesia with ropivacaine administration (4, 11).

Dexmedetomidine is a highly selective α2-adrenergic agonist with sedative, analgesic, and sympatholytic properties. When combined with local anesthetics, dexmedetomidine enhances analgesic efficacy by inhibiting norepinephrine release and modulating nociceptive transmission in the central nervous system. In the present study, addition of dexmedetomidine contributed to stable hemodynamic parameters and effective postoperative analgesia without significant adverse effects. These findings correlate with studies conducted by Panda et al. and Sharma et al., who reported prolonged analgesic duration and reduced rescue analgesic consumption with dexmedetomidine-containing intraperitoneal regimens (12, 13).

The addition of tramadol further enhanced the analgesic profile in Group RDT. Tramadol exerts its analgesic action through weak μ-opioid receptor agonism along with inhibition of serotonin and norepinephrine reuptake, thereby producing multimodal analgesia. The present study found significantly prolonged time to first rescue analgesia in the RDT group compared with the RD group. This observation is consistent with findings by Kumari et al., who demonstrated lower postoperative pain scores and decreased fentanyl consumption in patients receiving intraperitoneal

ropivacaine with tramadol (10). Similarly, Shukla et al. reported superior analgesia and reduced analgesic requirement when tramadol was added to intraperitoneal local anesthetics during laparoscopic cholecystectomy (9).

In the current study, VAS scores were significantly lower in the RDT group during the first six postoperative hours. This early pain reduction is clinically important because visceral pain is most intense during the immediate postoperative period. Comparable results were reported by Thomas et al., who observed lower VAS scores and prolonged postoperative analgesia with dexmedetomidine-based intraperitoneal analgesia compared with fentanyl combinations (14). Likewise, Miao et al. demonstrated improved quality of recovery and lower postoperative pain scores with intraperitoneal ropivacaine and dexmedetomidine in laparoscopic hysterectomy patients (15).

An important finding of the present study was the significant reduction in total postoperative analgesic consumption in Group RDT. Reduced opioid and rescue analgesic requirement is advantageous because it minimizes opioid-related adverse effects such as nausea, vomiting, sedation, constipation, and respiratory depression. Multimodal analgesia strategies that reduce opioid exposure are increasingly encouraged in enhanced recovery after surgery (ERAS) protocols. Kehlet emphasized that effective multimodal analgesia contributes to accelerated postoperative recovery and improved patient outcomes (16).

Hemodynamic stability was maintained in both study groups throughout the postoperative period. No significant episodes of bradycardia, hypotension, respiratory depression, or excessive sedation were observed. These findings support the safety profile of dexmedetomidine and tramadol when administered intraperitoneally in recommended doses. Similar safety observations were reported in previous randomized controlled trials evaluating intraperitoneal analgesic combinations (9, 13).

The limitations of the present study include its single-center design and relatively modest sample size. Furthermore, long-term outcomes such as chronic pain development and patient satisfaction beyond 24 hours were not evaluated. Future multicentric studies with larger populations and extended follow-up are recommended to validate these findings and establish standardized intraperitoneal analgesic protocols.

CONCLUSION

Intraperitoneal instillation of ropivacaine with dexmedetomidine and tramadol provided superior postoperative analgesia compared to ropivacaine with dexmedetomidine alone in patients undergoing laparoscopic cholecystectomy. The addition of tramadol significantly reduced postoperative pain scores, prolonged the duration of analgesia, delayed the requirement for first rescue analgesia, and decreased total postoperative analgesic consumption within 24 hours. Both analgesic regimens maintained stable hemodynamic parameters without significant adverse effects. Therefore, the combination of ropivacaine, dexmedetomidine, and tramadol can be considered an effective, safe, and reliable multimodal analgesic technique for improving postoperative pain management and enhancing patient recovery following laparoscopic cholecystectomy.

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